UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND EVALUATION OF NEW PROTOTYPE SEAT FOR COMMERCIAL STAGE BUS DRIVERS

WAN CHIK ZAHARAH BT. WAN HASSAN

FPSK(m) 2009 13

DEVELOPMENT AND EVALUATION OF NEW PROTOTYPE SEAT FOR COMMERCIAL STAGE BUS DRIVERS

By

WAN CHIK ZAHARAH BT. WAN HASSAN

Thesis Submitted to the School of Graduates Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the degree of Master of Science

July 2009

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DEVELOPMENT AND EVALUATION OF NEW PROTOTYPE SEAT FOR COMMERCIAL STAGE BUS DRIVERS

By

WAN CHIK ZAHARAH BT. WAN HASSAN
July 2009

Chairman: **Shamsul Bahri Hj. Mohd Tamrin, PhD**

Faculty: **Medicine & Health Sciences**

As a developing country, Malaysia has experiencing rapid development in public transport due to the process of urbanization, economic development and population growth. This rapid increase in the total number of vehicles on roads created traffic congestion. Previous study had reported that bus drivers were highly exposed to ergonomic hazards due to poor seat design. Prolong exposure resulted in the incidence of having low back pain. Thus, a cross sectional study was carried out among Malaysian male bus drivers from July 2004 to January 2006 with the main objective of developing a new bus driver's seat design based on anthropometric measurements of Malaysian males. A total of 669 respondents were selected using a stratified random sampling from central, eastern, northern and southern regions of Peninsular Malaysia. Modified Nordic questionnaires were used to determine demographic information, prevalence of low back pain and risk factors associated with low back pain (LBP) among the bus drivers. Martyn Type Anthropolometer was used to measure anthropometrics parameters namely sitting eye height, sitting shoulder height, elbow rest height, popliteal height with shoes, popliteal height without shoes, knee height with shoes, knee height without shoes, elbow breadth, hip breadth, buttock to popliteal length, buttock to knee length and lumbar support height. Measurements for current bus seat taken were backrest height, backrest width, seat pan depth, seat pan width and seat height. Rapid Upper Limb Assessment (RULA) was used to simulate the RULA score of the proposed seat design. The result showed a high prevalence of life time low back pain (59.5%) among Malaysian male bus drivers in Peninsular Malaysia. Logistic regression analysis showed that low back pain was significantly associated ($p>0.05$) with exposure to vibration (2.285, 95% CI 1.610 - 3.243), prolonged sitting (2.729, 95% CI 1.525 - 4.886), hard cushion (2.586, 95% CI 1.396 - 4.788), uncomfortable seat (2.256, 95% CI 1.346 - 3.782), bending (3.928, 95% CI 0.854 - 6.076) and lifting load while working (1.087, 95% CI 0.603 - 1.959). Anthropometric measurements obtained from this study were used as a guide in designing a new seat. The current seat measurements were significantly different ($p<0.05$). RULA simulation showed that the new proposed seat had an acceptable score of 2 while for the current seat score 3. The current seat contributed to the LBP and newly improved seat can be designed and developed using the anthropometric as well the RULA analysis method.

Key words: bus drivers, low back pain, anthropometry, seat design, RULA, Malaysia

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PEMBANGUNAN DAN PENILAIAN PROTOTAIP BARU KERUSI UNTUK PEMANDU BAS KOMERSIL

Oleh

WAN CHIK ZAHARAH BT. WAN HASSAN
Julai 2009

Pengerusi: **Shamsul Bahri Hj. Mohd Tamrin, PhD**

Fakulti: **Perubatan & Sains Kesihatan**

Malaysia sebagai sebuah negara membangun telah menunjukan perkembangan yang pesat dalam industri pengangkutan awam. Kesan pertumbuhan kepadatan penduduk yang tinggi, pembangunan ekonomi dan urbanisai secara tak langsung telah meningkatkan pertambahan jumlah kenderaan pengangkutan awam. Peningkatan ini menyebabkan pemandu kenderaan komersil terdedah kepada pelbagai masalah kesihatan pekerjaan. Kerusi bas yang tidak ergonomik dan akibat duduk terlalu lama akan meningkatkan lagi risiko untuk mendapat masalah sakit belakang. Justeru itu satu kajian analitikal keratan rentas telah dijalankan di kalangan pemandu bas Malaysia pada Julai 2004 sehingga Januari 2006 bertujuan untuk merekabentuk kerusi baru bagi pemandu bas berdasarkan pengukuran anthropometrik pemandu bas lelaki Malaysia. Seramai 669 orang responden telah dipilih secara persampelan rawak tersusun dari bahagian wilayah tengah, timur, utara dan selatan Semenanjung Malaysia. Data demografi, prevalens sakit belakang bawah dan perhubungan faktor risiko dengan sakit belakang bawah telah diperolehi melalui soal-selidik Nordic yang telah diubahsuai. Alat Martyn Type Anthropolometer digunakan untuk memperolehi

data pengukuran anthropometrik dengan mengukur ketinggian aras mata-pinggul, ketinggian aras bahu-duduk, ketinggian aras siku-duduk, ketinggian aras popliteal dengan kasut, ketinggian aras popliteal tanpa kasut, ketinggian aras lutut dengan kasut, ketinggian aras lutut tanpa kasut, lebar siku-siku, lebar pinggul, panjang pinggul-popliteal, panjang pinggul –lutut dan ketinggian aras penyokong lumbar. Bagi pengukuran kerusi pemandu sekarang yang diukur adalah ketinggian penyandar belakang, lebar penyandar belakang, kedalaman tempat duduk, lebar tempat duduk dan ketinggian kerusi. Kaedah simulasi dengan menggunakan perisian *Rapid Upper Limb Assessment* (RULA) digunakan untuk memperolehi scor postur badan yang betul bagi merekabentuk kerusi pemandu bas baru. Hasil kajian menunjukan prevalens sakit belakang bawah yang pernah dialami sekali sepanjang hidup dikalangan pemandu bas Semenanjung Malaysia adalah tinggi iaitu 59.5%. Melalui ujian statistik analisis persamaan *linear* menunjukan sakit belakang bawah mempunyai perhubungan yang signifikan dengan faktor-faktor risiko iaitu pendedahan getaran (2.285, 95% CI 1.610 - 3.243), duduk terlalu lama (2.729, 95% CI 1.525 - 4.886), kusyen terlalu keras (2.586, 95% CI 1.396 - 4.788), kerusi tidak selesa (2.256, 95% CI 1.346 -3.782), membongkok ketika memandu (3.928, 95% CI 0.854 - 6.076) dan mengangkat beban ketika bekerja (1.087, 95% CI 0.603 - 1.959). Data pengukuran anthropometrik yang diperolehi melalui kajian ini digunakan sebagai rujukan dalam merekabentuk kerusi baru. Analisi ujian t mendapati bahawa terdapat perhubungan yang signifikan bagi pengukuran parameter antara kerusi baru dan kerusi sekarang ($p<0.05$). Hasil daripada simulasi yang dijalankan dengan menggunakan kaedah analisis RULA menunjukan bahawa rekabentuk kerusi baru adalah diterima dan sesuai dengan scor postur badan 2 manakala rekabentuk kerusi pemandu bas sekarang adalah tidak bersesuai dan tidak memenuhi keperluan populasi pemandu bas Malaysia dengan scor 3. Kerusi pemandu bas sekarang adalah merupakan faktor penyumbang kepada sakit belakang bawah dan kerusi pemandu bas baru boleh direkabentuk dan dibangunkan menggunakan kaedah anthropometrik serta kaedah analisis RULA.

Kata kunci: pemandu bas, sakit belakang bawah, anthropometri, rekabentuk kerusi, RULA, Malaysia

ACKNOWLEDGEMENTS

Praise to Allah S.W.T on all the blessings this research is successfully completed. A very deep appreciation to Dr. Shamsul Bahri Bin Hj. Mohd Tamrin as my supervisor, who had patiently advised, guided and encouraged throughout the course of this research. A very great thankful to my co-supervisors Professor Dr. Nasaruddin Abdul Aziz and Associate Professor Dr. Rosnah Mohd Yusoff for their full support throughout this research. Not to forget, Mr. Rosnan Hamzah, Mr. Hamiraj Abdul Hamid, Mr. Ahmad Rizal Abdul Rahman, Dr. Juliana Jalaluddin, Dr. Mohd. Nizam Jemoin, Mr. Mohamad Faizal Che Leh and fellow lecturers, tutors and all the staffs of Environmental and Occupational Health Unit for their help rendered.

Special thanks to Mr. Azlan Bin Ariffin, Miss Shahartini Hanafi Bt. Hanafi, Miss Salawati Bt. Yahya and Mr. Hafidzi Bin Hanafi for all the help and support during data collection. I would also like to thank my fellow course mates and friends that I am not able to mention here.

I would like to thank all the bus companies and the bus drivers. Without them this project will not be successful. Thank to Ministry of Science and Innovation of Malaysia (MOSTI) who gave fund and support through this project. The study was supported by under the Intensified Research of Priority Area (IRPA) grant of 8th Malaysian Plan (06-02-05- 0000-PR0061/0).

Last but not least, heartfelt gratitude to my beloved family especially my parents, Hj. Wan Hassan Bin Hj. Wan Othman and Hjh Zaiton Bt. Hj. Ismail for their support and understanding and also all my siblings; for their unconditional support and help that enable me to complete this research.

I certify that a Thesis Examination Committee has met on 14 July 2009 to conduct the final examination of Wan Chik Zaharah Bt. Wan Hassan on her thesis entitled "Development and Evaluation of New Prototype Seat for Commercial Stage Bus Drivers" in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Pertanian Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Lye Munn Sann, PhD
Professor Dato'
Faculty of Medicine & Health Sciences
Universiti Putra Malaysia
(Chairman)

Mohd. Roslan Bin Sulaiman, PhD
Professor
Faculty Medicine & Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Zailina Bt. Hashim, PhD
Professor
Faculty of Medicine & Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Krishna Gopal Rampal, PhD
Community Health Department
Faculty of Medicine
Universiti Kebangsaan Malaysia
(External Examiner)

BUJANG BIN KIM HUAT, PhD
Professor and Deputy Dean
School of Graduates Studies
Universiti Putra Malaysia

Date: 24 December 2009

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Master of Science**. The members of the Supervisory Committee were as follows:

Shamsul Bahri Hj. Mohd Tamrin, PhD
Faculty of Medicine & Health Sciences
Universiti Putra Malaysia
(Chairman)

Nasaruddin Abdul Aziz
Professor
Faculty of Medical
Cyberjaya Medical College
(Member)

Rosnah Mohd Yusoff, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduates Studies
Universiti Putra Malaysia

Date: 14 January 2010

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

WAN CHIK ZAHARAH BT. WAN HASSAN

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

WHO	World Health Organization
LBP	low back pain
MOH	Ministry of Health
et al.	and others
No.	number
OR	odds ratio
WBV	whole-body vibration
NIOSH	National Institute of Occupational Safety and Health
MSD	musculoskeletal disorders
BMI	body mass index
m	meter
cm	centimetre
mm	milimeter
kg	kilogram
CI	confidence interval
SD	standard deviation
N	total of sample
%	percentage
>	more than
<	less than
=	equals to
IRPA	Intensification of Research in Prioritised Area
$\mathbf{H^+}$	Hydrogen
$\mathbf{Na^+}$ **-**	Natrium

Ka^+	Kalium
ISO	International Standard Organisation
ACGIH	American Conference of Government Industrial Hygienist
EMG	electromyography
RULA	Rapid Upper Limb Assessment
°	degree
e.g.	example
E	scaling factor

LIST OF APPENDICES

CHAPTER 1

PREFACE

1.1 Introduction

As a developing country, Malaysia has experiencing rapid development in the field of road transport due to the process of urbanization, economic development and population growth. This rapidity experiencing has increased the total number of vehicles on roads. The increased traffic volumes on roads can create traffic problems among drivers.

According to Road and Transport Department (2007), there were about 959 714 new registered motor vehicles in Malaysia including motorcycle, motorcar, public transport, taxi, hire and drive car, good vehicles and other vehicles. Hence from that grand total it was about 62 308 registered public transport which were stage bus, express bus, mini bus, school bus, employee bus, excursion bus and chartered bus. In

2007 there were about 99 683 public service drivers registered with Road and Transport Department in Malaysia.

Buses are one of the commercial vehicles chosen by many people as a mode of transportation to go anywhere as it is the cheapest and easy to get. Bus driving is characterized by psychological and physical stresses. Most severe are the stresses of traffic in big cities, because of the heavy traffic and frequent stops (Alfons & Andreas, 1998).

Bus drivers have big responsibilities and risks because they carry many passengers every day to anywhere. In most transit companies, the drivers must handle tasks such as selling tickets, observing passenger loading and unloading and providing information to passengers (Alfons & Andreas, 1998). Thus means, the bus drivers most probably expose to occupational safety and health hazard during their work.

The World Health Organization (WHO, 1998) reported that there were more than a million cases of neck and back disorders worldwide and they ranked second after iron deficiency anemia. There were about 250 000 cases of neck and back disorders were due to occupational injury as reported by WHO (1998). While in Malaysia, it was reported that 18 027 cases of all musculoskeletal disorders (MSDs) (Ministry of Health, 1996).

Many studies have investigated back pain among professional drivers. Low back pain (LBP) is a significant health problem for professional drivers compared to the general population with higher incidence of low back pain (Troup, 1978). LBP is also considered as one of the most common health problems around the world and one of the most difficult health problems to treat. It is often associated with functional disabilities and therefore has economic, social, industry and health care system implicating (Khalil et al., 1993).

As reported by Bovenzi & Zadini (1992) and Troup (1978), factors such as frequent awkward postures, muscular effort, vibration, shock and whole-body vibration (WBV) exposure and finally prolonged sitting in a constrained position contribute to overwork of the lumbar spine and its supportive structures, causing LBP.

Olanrewaju et al. (2007) studied on the exposure to posture demands, manual materials handling (MMH) and WBV as risks for LBP among 80 city bus drivers for three models of bus (a mini-bus, a single-decker bus, a double-decker bus). The results showed that city bus drivers spend about 60% of the daily work time actually driving, often with the torso straight or unsupported, perform occasional and light MMH, and experience discomforting jerking vibration events. Transient and mild LBP (not likely to interfere with work or customary levels of activity) was found to be prevalent among the drivers and a need for ergonomic evaluation of the drivers' seat was suggested.

The findings were supported by NIOSH (US) (1997), there was strong evidence of an association between MSDs with workplace physical factors, and non-work related characteristics. Non-work related characteristics include physical fitness, anthropometric measures, lumbar mobility, physical strength, medical history and structural abnormalities of the individuals. Workplace physical factors include heavy physical work, lifting and forceful movements, awkward postures, WBV and static working postures. Static work postures of prolonged standing, sitting and sedentary work are isometric positions where very little movement took place.

The driver's workstation in buses was designed in the form of a half - open cabin. Alfons & Andreas (1998) suggested that ergonomic design of the driver's workstation was a necessary component of driver safety and health protection. Technical measure was the ergonomically optimal design of the driver's workstation.

Not many studies have been done by researchers in Malaysia to identify risk factors of occupational safety and health problem among commercial vehicle drivers. Lack of awareness and preliminary data of MSDs among commercial vehicle drivers in Malaysia will lead to reduced productivity due to pain, discomfort and illness in a worker. Detection and intervention at an early stage could possibly affect workers physically and mentally. Therefore it is a necessary to carry out a new study among commercial vehicle driver in Malaysia that focuses on their work environment that relate to risk factors of occupational safety and health problem that would eventually improve work tasks and eliminate or reduce the MSDs problems.

1.2 Problem Statements

MSD is considered a major problem among commercial vehicle drivers not only in Malaysia but also worldwide. A higher incidence of musculoskeletal problems was reported among transit bus drivers compared to the general population (as high as 3 times greater) (Courtney & Evans, 1987).

Many studies have reported a higher percentage of bus drivers having musculoskeletal complains. Maciulyte et al. (2000) reported that many vehicle drivers experienced problems on their skeletal muscles, cardio vascular and digestive systems. In United States, Magnusson et al. (1996) examined a group of professional drivers, and found that 50% of the subjects' complained of neck, shoulder and back pain.

A study conducted by Maciulyte et al. (2000) found that 57% drivers experienced skeletal muscle symptoms such as cramps, aches and discomfort on their back, legs and hands. Gilmore et al. (1997) reported that, the primary interest in the bus driver's workstation was the relationship between the driver's seat, steering column and wheel and pedals. Bus drivers were required to interact and maintain constant with each of these components. It was the use and combination of these components that influence the bus driver's posture.

The prevention of MSDs can be achieved by interventions which reduce the probability and severity of injuries. It is estimated that through ergonomics design, up to one-third of compensable LBP in industry can be reduced (Levy & Wegman, 1995). More than 70% of workers in developed countries have sedentary jobs (Reinecke et al. 1994) and concern about musculoskeletal problems have led to the increasing application of ergonomics in changing the workplaces to provide good sitting postures (Alfons & Andreas, 1998).

As LBP is considered a major problem among commercial vehicle drivers and the most of the risk factors had been identified, there is an urgent need for us to study the current seat used by Malaysian bus operators, proposed a new seat design and eventually reduce the high prevalence of LBP. Many bus manufacturers view the bus driver's seat as an add-on or afterthought. Typically, the bus interior is designed to optimize the number of passenger seats. The workstation is cramped with instrumentation and a fare box. The bus driver's seat is fitted within this space. The design of the bus driver's workstation must not just take into consideration the tasks performed by the bus driver. The design must also consider the physical characteristics of the driver and the accommodations required that permit the full range of seat adjustments (Alfons & Andreas, 1998 and Saporta, 2000).

Evidence by Courtney & Evan (1987) among Chinese bus driver, reported that bus seat built with European anthropometry did not match with the anthropometry of Chinese bus drivers in Hong Kong. This resulted in an improper add on such as brick or a piece of wood for foot rest and padding of rags or rubber shoe bottoms on the pedals to fit their size. The inappropriate anthropometric data used resulted in poor design, with the workforce modifying the workstation to accommodate their needs. It can be observed that workplace design should concentrate on the need for operators to vary their sitting behavior according to job requirements rather than on finding a single, so-called optimal position (Grieco 1986).

Alfons & Andreas (1998) and Harrison et al. (2000) suggest that modification of the bus seat itself will reduce the prevalence of MSDs. These modifications include seat adjustment such as (1) backrest inclination, (2) lumbar support (up/down translation), (3) seat height adjustment, (4) seat bottom, (5) seat back (forward/backward), (6) armrest, (7) headrest and (8) shock absorbers to dampen WBV (Harrison et al., 2000). Bovenzi et al. (1992) reported that these modifications will reduce LBP up to 86% reduction of time off per injury and 78% reduction in the frequency of workstation related injuries.

Currently, Malaysian bus operators only considering on the driver's workstation and the tasks performed by them but failed to consider the physical characteristics of the driver such as their size and anthropometry. This physical characteristic required a full range of seat adjustments based on Malaysian anthropometry. Evidently, most of Malaysian bus operators tend to buy their bus seat from either European or Korean seat that does not accommodate our Malaysian drivers.

The aim of this study are to determine the prevalence of LBP among Malaysian bus drivers and recommend a new seat design based on anthropometric measurement of Malaysian bus drivers and also to evaluate the effectiveness of the new seat design.

1.3 Study Justification

This study will develop a bus seat prototype based on Malaysian adult male anthropometry. This will be the first time a Malaysian anthropometric data will be used in developing a new bus seat specifically for Malaysian drivers. This seat will be designed with the objective of reducing MSD problem among the bus drivers due to occupational health injury at workplace. Therefore it will eventually increase in workers productivity due to pain and discomfort. It is important to create a healthy working condition and environment at workplace.

It is a necessary to establish the causes of MSDs among drivers and to identify the prevalence of the MSDs among vehicles drivers in Malaysia. Furthermore, this study could generate data to use as baseline for MSDs among Malaysian vehicles drivers. Solution and recommendations may be derived from this study to improve the situations and problems in future.

This study will also benefit both the government and the private sector especially that involved with the Ministry of Transportation such as the Road and Transport

Department, Road Safety Council, Commercial Vehicle Licensing Board in the development of new standard of bus drivers' seats. The owner of public busses such as RAPID KL and TransNasional will also benefit focus the reduce cost of importing seats from other countries such as United Kingdom and South Korea.

1.4 Conceptual Framework

There are 3 main factors shown in Figure 1.1, which contribute to low back pain namely (1) ergonomics factors, (2) environmental factors and (3) social demographic factors. In this study, only the ergonomics factors and environmental factors will be considered.

There are 3 main factors that contribute to ergonomics. They are (1) anthropometry (2) vibration and (3) postures. The anthropometry of bus drivers taken were (1) sitting eye height, (2) sitting shoulder height, (3) popliteal height, (4) hip breadth, (5) buttock to popliteal length (6) elbow to elbow breadth and (7) lumbar height. The unsuitable seat design could result bad postures among bus drivers to prevail, hence create the LBP problems.

WBV is mainly transferred to the bus drivers from the engine and road surface. Vibrations from the engine are transferred via the steering wheel while the road surface will cause vibration to the bus and this will be transmitted to the bus drivers through the bus floor and seat pan.

The third ergonomics factor is posture of the bus driver, especially in sitting position. When a seat and the work area are not compatible will lead to awkward postures requiring twisting and bending. The duration of driving also plays an important role as prolonged seating will lead to muscle fatigue and eventually LBP.

Therefore based on ergonomics factors, parameters that will be used in proposing a new seat prototype are (1) adjustable sitting height, (2) adjustable seat pan, (3) adjustable backrest and (4) adjustable lumbar support. All these parameters will be used based on adult male Malaysian bus drivers' anthropometry.

The second factor is social demographic factor such as age, body mass index, smoking habit, diseases and injury in the past had been reported as a risk factors influencing MSD especially with regards to LBP.

The final factor includes environmental factors such as road condition, age of buses, type of buses (fully automated or manual buses) and unsuitable current seat. The current seat bus driver's is not designed based on Malaysian anthropometric measurements. The unsuitable current seat will lead to muscle fatigue due to no blood circulation and movement (prolonged sitting).

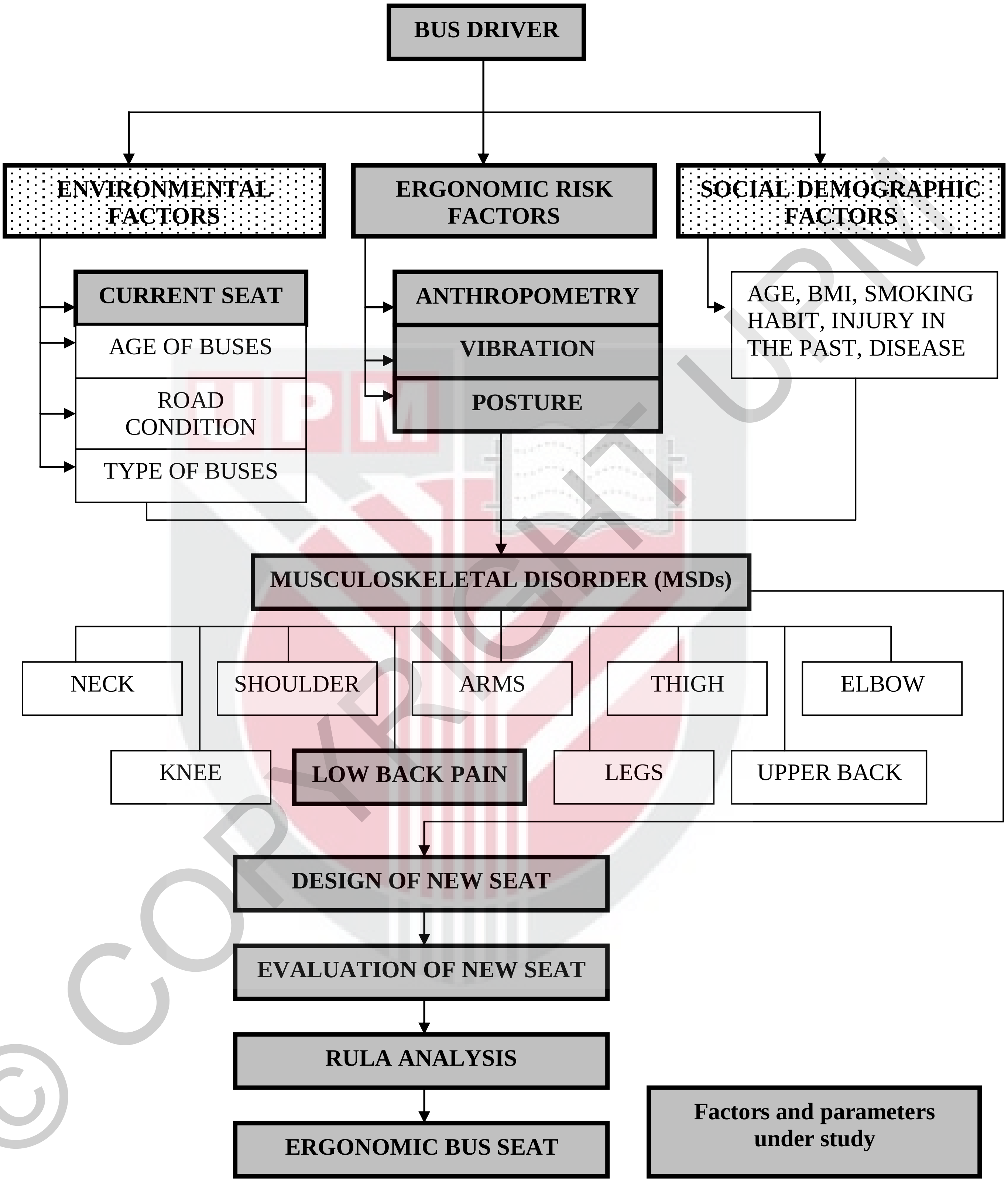

Figure 1.1 Conceptual framework factors contributing to musculoskeletal problem and development of prototype new seat design in reducing low back pain

1.5 Study Objectives

1.5.1 General objective

The aim of the study is to develop an ergonomically designed seat based on the anthropometric measurements to reduce ergonomic risk factors for LBP among bus drivers.

1.5.2 Specific objectives

1. To determine the anthropometric measurements of bus drivers.
2. To determine the prevalence of LBP among bus drivers.
3. To determine the ergonomic risk factors of LBP among bus drivers.
4. To determine the association between ergonomic risk factors and LBP among bus drivers.
5. To evaluate the new bus driver seat design using Rapid Upper Limb Assessment (RULA).
6. To compare the new propose seat design based on anthropometric measurement with current seat.

1.6 Study Hypothesis

1. There is a significant association between ergonomic risk factors and LBP among bus drivers.
2. There is a significant different between current seat design anthropometric with new seat design.

1.7 Terminology

1.7.1 Body Mass Index (BMI)

Conceptual Definition

A value that explain the obesity of an individual without showing the body weight (WHO, 1997).

Operation Definition

Classification of body weight and the height of a person by using the formula below (WHO, 1997):

$$\mathbf{BMI} = \frac{\textbf{Weight (kg)}}{\textbf{Height (m)}^2}$$

The indicators of BMI are as below: -

BMI < 18.5	= Underweight.
BMI 18.5-22.9	= Normal range.
BMI ≥ 23	= Overweight.
BMI 23.0 – 27.4	= Pre-obese
BMI 27.5 – 34.9	= Obese I
BMI 35.0 – 39.9	= Obese II
BMI ≥ 40.0	= Obese III

1.7.2 Low Back Pain

Conceptual Definition

Pain sensation beginning from muscle attachment at the ribcage down to gluteal fold area (Nachmeson, 1992).

Operational Definition

Low back pain is obtained from the Standard Nordic Questionnaires (SNQ) based on body map diagram. (Kuorinka et al. 1987). Figure 1.2 shows the approximately position parts of the body where the participants had ache, pain or discomfort.

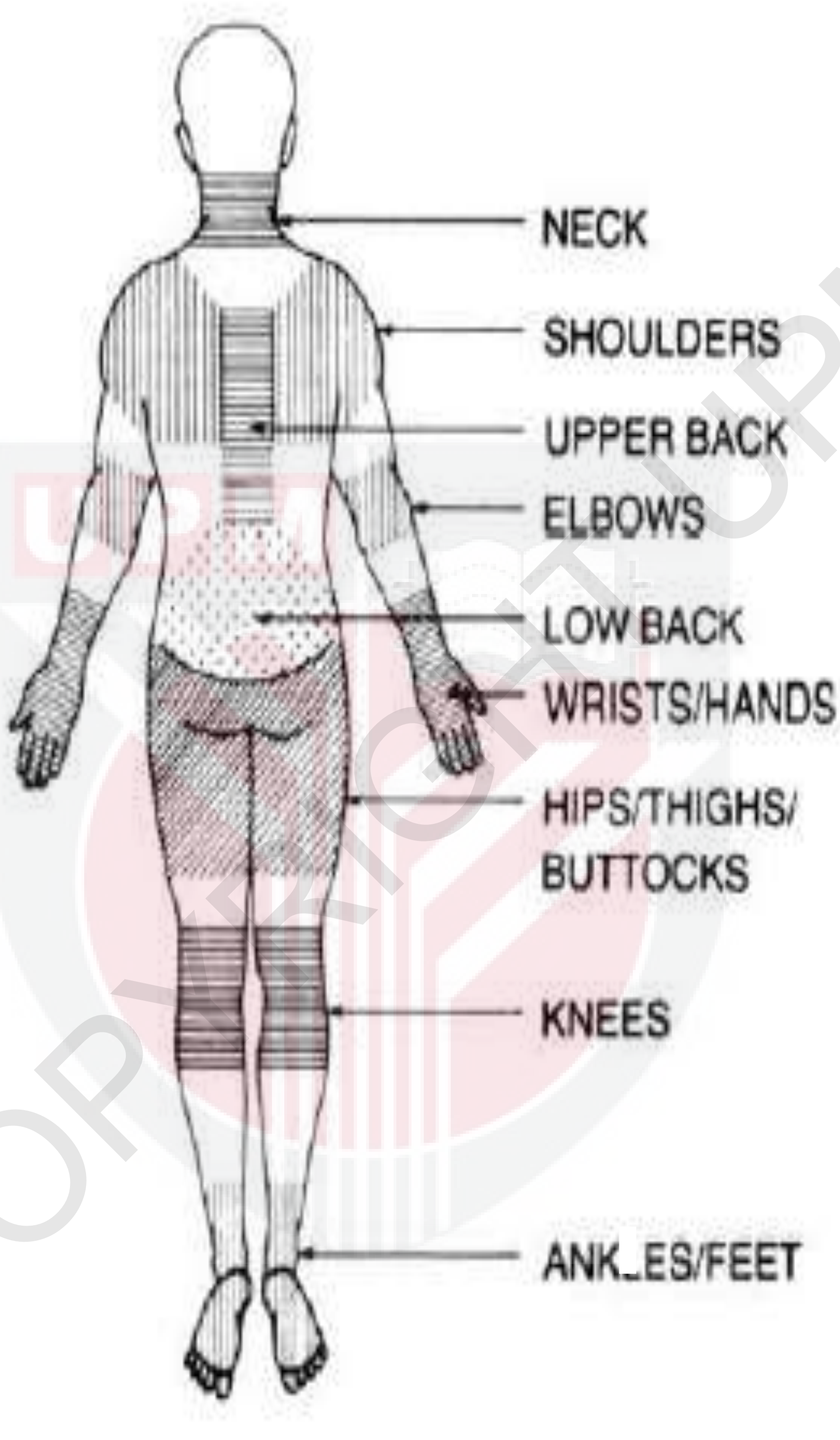

Figure 1.2 Parts of body

(Source: Kuorinka et al. 1987)

1.7.3 Popliteal Height

Conceptual Definition

Vertical distance from the floor to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into lower leg (Pheasant, 1996).

Operational Definition

The height of the underside of the thigh immediately behind the knee with the subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.4 Buttock to Popliteal Length

Conceptual Definition

Horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meet the underside of the thigh (Pheasant, 1996).

Operational Definition

The horizontal distance from the rearmost surface of the buttock to the back of the lower leg with the subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.5 Hip Breadth

Conceptual Definition

Maximum horizontal distance across the hips in the sitting position (Pheasant, 1996).

Operational Definition

The breadth of the body taken laterally across the widest portion of the hips with subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.6 Sitting Shoulder Height

Conceptual Definition

Vertical distance from the seat surface to the acromion (i.e the bony point of the shoulder) (Pheasant, 1996).

Operational Definition

The height of the uppermost point of the clavicle above the sitting surface with the subject sitting erect and looking straight ahead.

1.7.7 Elbow to Elbow Breadth (shoulder breadth – bideltoid)

Conceptual Definition

Maximum horizontal breadth across the shoulder, measured to the protrusions of the deltoid muscles (Pheasant, 1996).

Operational Definition

The distance across the lateral surfaces of the elbows with the subject sitting erect, upper arms, vertical and touching the side, forearms held horizontally and looking straight ahead**.**

1.7.8 Knee Height

Conceptual Definition

Vertical distance from the floor to the upper surface of the knee (usually measured to the quadriceps muscle rather than the kneecaps) (Pheasant, 1996).

Operational Definition

The height of the uppermost point on the knee with the subject sitting erect, knees and ankles are at right angles and looking straight ahead

1.7.9 Sitting Eye Height

Conceptual Definition

Vertical distance from the sitting surface to the inner canthus (corner) of the eye (Pheasant, 1996).

Operational Definition

The height of inner corner of the eye above the sitting surface with the subject sitting erect and looking straight ahead.

REFERENCES

Abdul, R. 2001. *Whole-Body Vibration and Low Back Pain among Drivers in Health Department in The State Of Pahang, Darul Makmur*. Projek Ilmiah Akhir. Bachelor Sains Keselamatan Pekerjaan & Persekitaran.. Universiti Putra Malaysia. Serdang. Selangor.

Afrul, O.N. 2002. *The Effects of Whole Body Vibration to Trapezius Muscle among Army Truck Drivers In Markas Latihan Tentera Taiping, Perak Darul Ridzuan*. Ilmiah Akhir. Bachelor Sains Keselamatan Pekerjaan & Persekitaran.. Universiti Putra Malaysia. Serdang. Selangor

Alfons, G. and Andreas, M. 1998. *Ergonomics of bus driving*. *In* Encyclopedia of Occupational Health & Safety. Edited by Janne, M.S. 4th Edition. Ch. 102. Transport Industry and Warehousing. Geneva : International Labour Office. Vol. 3, pt. XVII.

Andersson, G.B.J. 1981. Epidemiologic aspects on low-back pain in industry. *Spine*. 6: 53 – 60.

Anderson, R. 1992. The back pain of bus drivers. Prevalence in an urban area of California. *Journal of Spine***.** 17: 1481 – 1488.

Andersson, G.B.J. 1999. Epidemiological features of chronic low back pain. *The Lancet.* 354: 581 - 585.

Asif, Y. 2002. *Getaran Seluruh Badan dan Kesan ke atas Otot Trapezius Di Kalangan Pemandu Bas Awam*. Projek Ilmiah Akhir. Bachelor Sains Keselamatan Pekerjaan & Persekitaran.. Universiti Putra Malaysia. Serdang. Selangor.

Backman, A.L. 1983. Health survey of professional drivers. *Scandinavian Journal of Work, Environment and Health*. 9: 30 – 35.

Backman, A.L. and Jarvinen, E. 1983. Turnover of professional drivers. *Scandinavian Journal of Work, Environment and Health*. 9: 36 – 41.

Bernard, B.P. and Fine, I.J. 1997. Musculoskeletal Disorder and Workplace Factors. US Department of Health & Human Services. National Institute for Occupational Safety & Health.

Bongers, P.M., de Winter, C.R., Kompier, M.A.J. and Hildebrandt, V.H. 1993. Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work, Environment and Health*. 19: 297 – 312.

Boshuizen, H.C., Bongers, P.M. and Hulshof, C.T. 1992. Self-reported back pain in fork-lift truck and freight-container tractor drivers exposed to whole-body vibration. *Spine*. 17(1): 59 - 65.

Bovenzi, M. and Zadini, A. 1992. Self-reported low back symptoms in urban bus drivers exposed to whole-body vibration. *Spine Journal*. 17: 1048 – 1059.

Bovenzi, M. and Betta, A. 1994. Low back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. *Journal Applied Ergonomics*. 25: 231 – 241.

Bovenzi, M. 1996. Low back pain disorders and exposure to whole-body vibration in the workplace. *Semin Perinatol*. 20: 38 – 53.

Bovenzi, M., Ruia, F., Negroa C., Agostina, F., Angotzib, G., Bianchib, S., Bramantib, L., Festab, G., Gattib, G., Pintob, G., Rondinab, L. and Stacchinib, N. 2006. An epidemiological study of low back pain in professional drivers. *Journal of Sound and Vibration*. 298: 514-539.

Burdof, A. and Sorock, G. 1997. Positive and negative evidence of risk factors for back disorders. *Scandinavian Journal Work Environment & Health*. 23: 243 - 256.

Campbell, N.A. and Reece, J.B. 2002. Biology. *Sensory and Motor Mechanisms-Movement and Locomotion*. International Edition. 6: 1081.

Cassinelli, E.H. and Kang, J.D. 2000. Current understanding of lumbar disc degeneration. *Operative Techniques in Orthopedics*. 10: 254-262.

Chaffin, D.B., Andersson, G.B.J. and Martin, B.J., 1991. *Occupational Biomechanics*. New York. John Wiley & Sons, Inc.

Chaffin, D.B. 2001. *Digital Human Modeling for Vehicle and Workplace Design*. USA. Society of Automotive Engineers (SAE), Inc.

Clausa, A., Hidesa, J., Moseleyb, G.L. and Hodgesa, P. 2008. Sitting versus standing: Does the intradiscal pressure cause disc degeneration or low back pain? *Journal of Electromyography and Kinesiology*. 18: 550-558.

Courtney, A.J. and Evans, W.A. 1987. A Preliminary Investigation of Bus Cab design for Cantonese Drivers. *Journals of Human Ergo logy*. 16: 163 - 171.

Daniel, W.W. 1999. *Biostatistics: A Foundation for Analysis in the Health Sciences*. Seven Edition. New York. John Wiley & Sons, Inc.

Damkot, D.K., Pope, M.H., Lord, J. and Frymoyer, J.W. 1984. The relationship between work history, work environment and low-back pain in men. *Spine*. 9(4): 395 - 399.

Eastman Kodak Company. 2004. *Kodak's Ergonomic Design for People at Work*. Second Edition. New York. John Wiley & Sons, Inc.

Ebraheim, N.A., Rollins, J.R. and R. Xu R. 1996. Projection of the lumbar pedicle and its morphometric analysis, *Spine Journal*. 21: 1296–1300.

Ebraheim, N.A., Hassan, A., Ming, L and Xu R. 2004. Functional anatomy of lumbar spine. *Seminar in Pain Medicine*. 2(3): 131-137.

EL. Falou, W., Duchene, J., Grabisch, M., Hewson, D., Langeron, Y. and Lino, F., 2003. Evaluation of driver discomfort during long-duration car driving. *Applied Ergonomics*. 34: 249 – 255.

Erdfelder, E., Faul, F. And Buchner, A. 1996. GOWER: A general power analysis program. *Behaviour Research Methods, Instruments, and Computers*. 28: 1-11.

Frank, J.W., Kerr, M.S., Brooker, A.S., Dernaio, S.E., Maetzel, A., Shannon, H.S., Sullivan, T.J., Norman, R.W. and Wells, R.P. 1996a. Disability resulting from occupational low-back pain.- What do we know about primary prevention-a-review of the scientific evidence on prevention after disability begins. *Spine Journal*. 21: 2908 - 2917.

Frank, J.W., Brooker, A.S., Dernaio, S.E., Kerr, M.S., Maetzel, A., Shannon, H.S., Sullivan, T.J., Norman, R.W. and Wells, R.P. 1996b. Disability resulting from occupational low-back pain 2..- What do we know about secondary prevention-a-review of the scientific evidence on prevention after disability begins. *Spine Journal*. 21: 2918 - 2929.

Fenety, A. and Walker, J.M. 2002. Short-term effects of workstation exercises on musculoskeletal discomfort and postural changes in seated video display unit workers. *Journal of Physical Therapy*. 82: 578 – 589.

Fernanda, D.S., Maria, A.A.N., Ana, C.C.M, Juliana, C.S. and Paulo, J.A. 2006. Comparison of mehods RULA and REBA for evalation of postural stress in odontological services. *Third International Conference on Production Research – Americas' Region 2006* (ICPR – AM06).

Ferguson, S.A. and Marras, W.S. 1997. A literature review of low back disorder surveillance measures and risk factors. *Clinical Biomechanics*. 12: 211 - 226.

George, A.M., Nancy, L.L., Gene, W.G. and Karen, C.B. 2004. *SPSS for Introductory Statistics: Use and Interpretation*. Second Edition. New Jersey. Lawrence Erlbaum Associates Publishers.

Gilmore, B.J., Bucciaglia, J., Lowe, B., You, H., and Freivalds, A. 1997. *Bus Operators Workstation Evaluation & Design Guidelines*. TCRP Report F-4. Transportation Cooperative Research Program (TCRP). Transportation Research Board.

Goats, G.C. 1994. Massage – the scientific basis of an ancient art: Part 2. Physiological and therapeutic effects. *Brit Journal of Sports Medicine*. 28: 153 – 156.

Grandjean, E. 1988. *Fitting the task to the man: A textbook of occupational ergonomics*. London. Taylor & Francis Publisher.

Grieco, A. 1986. Sitting posture: an old problem and a new one. *Journal of Applied Ergonomics*. 29: 345 – 362.

Guo, H.R., Chang, Y.C., Yeh, W.Y., Chen, C.W. and Guo, Y.L. 2004. Prevalence musculoskeletal disorder among workers in Taiwan: A nationwide study. *Journal of Occupational Health*. 46: 26 – 36.

Gyi, D.E. and Porter, J.M. 1999. Interface pressure and the prediction of car seat discomfort. *Journal of Applied Ergonomics*. 30: 99 – 107.

Hales, T.R. and Bernard, B.P. 1996. Epidemiology of work-related musculoskeletal disorders. *Orthopedic Clinics of North America*. 27: 679 - 709.

Haboubi, M.H. 1992. Anthropometry for a mix of different populations. *Journal Applied of Ergonomics*. 23 (3) : 191 – 196.

Hammings, K.R. 1974. Commercial vehicle cabs: design for packaging, access and visibility. *Proceedings of the Institution of Mechanical Engineers*. 188: 24 – 27.

Harrison, D.D., Harrison, S.O., Croft, A.C., Harrison, D.E. and Troyanovich, S.J. 2000. Sitting Biomechanics, Part II: Optimal car driver's seat and optimal driver's spinal model. *Journal Manipulative Physiology Therapy*. 23: 37 – 47.

Hartley, L.R and Mabbott, N.A. 1998. *Fatigue-Related Crashes: A summary of Characteristics and Prevalence*. Report No. 130. Institute for Research in Safety and Transport, Murdoch University, Murdoch, Western Australia.

Hodges, P.W. and Moseley, G.L. 2003. Pain and motor control of the lumbopelvic region: effect and possible mechanisms. *Journal Electromyogr Kinesiol*. 13: 361 – 370.

Hoogendoorn, W.E., van Poppel, M.N.M., Bongers, P.M., Koes, B.W. and Bouter, L.M. 2000. Systematic Review of psychosocial factors at work and private life as risk factors for back pain. *Journal of Spine.* 16: 2114 - 2125.

Hosea, T.M., Simon, S.R., Delatizky, J., Wong, M.A. and Hsieh, C.C., 1986. Myoelectric analysis of the paraspinal musculature in relation to automobile driving. *Journal of Spine*. 11: 928 – 936.

Hoy, J., Mubarak, N., Nelson, S., Sweerts L., Magnusson, M., Okunribido, O. and Pope, M. 2005. Whole body vibration and posture as risk factors for low back pain among forklift truck drivers. *Journal of Sound and Vibration*. 284: 933-946.

Hulshof, C.T.J. 1998. Whole-body vibration: an evaluation study. PhD. thesis. University van Amsterdam.

International Standard Organization. ISO 2631-1 1997. Mechanical Vibration and Shock- Evaluation of Human exposure to Whole Body Vibration. Part 1: General Requirement. International Standardization Organization.

James, P.K. 1999. *Ergonomic Process Management*: *A Blueprint for Quality and Compliance*. East Carolina University. Greenville, North Carolina. Lewis Publishers.

John, G. 1992. *The Evolution of Low Back Pain* (*Short Version*). United Kingdom. Bonsai Graphics Publisher.

Jellema, P., van Tulder, M.W., Van Poppel, M.N.M, Nachemson, A.L. and Bouter, L.M. 2001. Lumbar supports for prevention and treatment of low back pain. *Journal of Spine*. 26: 377 - 386.

Johanning, E., Wilder, D.G., Landrigan, P.J. and Pope M.H. 1991. Whole-body vibration in subway cars and review of adverse health effects. *Journal of Occupational Medicines*. 33: 605 - 612.

Johanning, E. 2000. Evaluation and management of occupational back disorder. *American Journal Industry Medicine*. 37: 94 - 111.

Khalil, T.K., Abdel-Moty, E.M., Rosomoff, R.S. and Rosomoff, H.L. 1993. *Ergonomics in Back Pain: a Guide to Prevention and Rehabilitation*. Van Nostrand Reinhold.

Kompier, M.A.J., Mulders, H., Meijman, T., Boersma, M., Groen, G. and Bullinga, R. 1990. Absence behavior, turnover and disability: A study among city bus drivers in the Netherlands. *Journal of Work & Stress*. 4: 83 – 89.

Kostova, V. and Kolevab, M. 2001. Back disorders (low back pain, cervicobrachial and lumbosacral radicular syndromes) and some related risk factors. *Journal of the Neurological Sciences*. 192: 17-25.

Kuorinka, I., Jonsson, B., Kilborn, A., Vinterberg, H., Biering – Sorensen F, Andersson, G. and Jorgensen, K. 1987. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Journal of Applied Ergonomics*. 18: 233 - 237.

Lay, W.E and Fisher, L.C. 1990. *Riding Comfort and Cushions*. USA. Society of Automotive Engineers (SAE), Inc.

Lahad, A., Malter, A., Berg, A.O. and Deyo, R. 1994. The effectiveness of four interventions for prevention of low back pain. *JAMA*. 272: 1286-1291.

Levy, B.S. and Wegman, D.H. 1995. *Occupational Health – Recognizing and Preventing Work-Related Disease*. Third Edition. Little, Brown and Company.

Lic. Ric O.D.B. and Veerle. H. 2000. *Research on work-related low back disorders*. European Agency for Safety and Health at Work. Belgium. (http://europa.eu.int)

Linton, S.J. and Van Tulder, M.W. 2001. Preventive interventions for back and neck pain problems: What is the evidence? *Journal of Spine*. 26: 778 - 787.

Li Z., Jiao, K., Chen, M., Wang, C.T. and Yang, Y.S. 2003. Spectral analysis of electromyography of low back muscle fatigue induced by simulated driving. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi*. 21: 365 – 367.

Lueder, R. 1996. A proposed RULA for Computer Users. *Proceeding of the Ergonomics Summer Workshop*. UC Berkeley Centre for Occupational and Environmental Health Continuing Education Program. San Francisco.

Mabbott, N., Gary Foster and Barbara Mc Phee. 2001. *Heavy Vehicle Seat Vibration and Driver Fatigue*. Australa Transport Safety Bureau PO Box 967 Civic Square Act 2608

Maciulyte, N. 2000. *Bus Driver Health and Codition of Work*. ECOHSE 2000 Symposium, Kaunas, Lithuania: 4 – 7 Oktober 2000.

Magnusson, M.L., Pope, M.H., Wilger, D.G. and Areskoug, B. 1996. Are occupational driver at an increased risk for developing musculoskeletal disorder? *Journal of Spine*. 21: 710 -717.

Maher, C.G. 2000. A systematic review of workplace interventions to prevent low back pain. *Australian Journal of Physiotherapy*. 46: 259: 269.

Mahone, D.B. 1995. A practitioner's guide to evaluating manual materials handling hazards. *Professional Safety*.

Marieb, E.N. 2006. *Essentials of Human Anatomy and Physiology*. 8th Editions. Pearson Benjamin Cummings Publisher. San Fransisco.

Marieb, E.N. 2004. *Human Anatomy and Physiology*. 6th Editions. Pearson Benjamin Cummings Publisher. San Fransisco.

Marras, S.W. 2001. Spine biomechanics, government regulation, and prevention of occupational low back pain. *Journal of Spine*. 1: 163 –165.

Massacessi, M., Pagnotta, A., Socetti, A., Masali, M., Masiero, C. and Greco, F. 2003. Investigation of work-related disorders in truck drivers using RULA method. *Journal* of *Applied Ergonomics*. 34:303 - 307.

Mbaye, I., Fall, M.C., Wone, I., Dione, P., Ouattara, B. and Sow, M.L. 2002. Chronic low back pain at a public transportation company in Senegal. *Dakar Med*. 47: 176 – 178.

McAtamney, L. and Corlet, N.E. 1993. RULA: a survey method for the investigation of work-related upper limb disorders. *Journal of Applied Ergonomics*. 24: 91 - 99.

Mcgill, S.M., Hughson, R.L. and Parks, K., 2000. Lumbar erector spinae oxygenation during prolonged contractions: Implications for prolonged work. *Journal of Applied Ergonomics.* 43: 486 – 493.

Mehlinga, W.E. and Krause, N. 2005. Are difficulties perceiving and expressing emotions associated with low-back pain?: The relationship between lack of emotional awareness (alexithymia) and 12-month prevalence of low-back pain in 1180 urban public transit operators. *Journal of Psychosomatic Research.* 58 (1): 73-81.

Ministry of Health. 1996. *Annual Reports 1995*. Government Publishing. Kuala Lumpur. Table 8: pp 27

Mohd, R.A. 2002. *Getaran Seluruh Badan Dan Kesannya ke atas Otot Spina Erektor Di Kalangan Pemandu Bas*. Projek Ilmiah Akhir. Bachelor Sains Keselamatan Pekerjaan & Persekitaran.. Universiti Putra Malaysia. Serdang. Malaysia.

Mundt, D.J., Kelsey, J.L., Golden, A.L., Pastides, H., Berg, A.T., Sklar, J., Hosea, T. and Panjabi, M.M. 1993. An epidemiologic study of non occupational lifting as a risk factor for herniated lumbar intervetebral disc. The northeast collaborative group on low back pain. *Journal of Spine*. 18: 595 – 602.

Nachemson, A.L. 1992. Newest knowledge of low back pain. A critical look. *Journal Clinical Orthopology*. 279: 8 - 20.

National Institute for Occupational safety and Health (NIOSH). 1997. *Musculoskeletal Disorder and Workplace Factors.* U.S. Department of Health & Human Service. USA.

Okunribidoa, O., Magnussona, M. and Popea, M. 2006. Low back pain in drivers: The relative role of whole-body vibration, posture and manual materials handling. *Journal of Sound and Vibration*. 298: 540-555.

Olanrewaju, O., Okunribido, O., Steven, J. S., Marianne, M and Popea, M. 2007. City bus driving and low back pain: A study of the exposures to posture demands, manual materials handling and whole-body vibration. *Journal of Applied Ergonomics*. 38: 29 - 38.

Olszewski, A.D., Yaszemski, M.J. and White, A.A. 1996. The anatomy of the human lumbar ligamentum flavum, *Journal of Spine*. 21: 2307–2312

Palmer, K.T., Griffin, M.J., Sydall, H.E., Pannet, B., Cooper, C., Coggan, D. 2003. The relative importance of whole-body vibration and occupational lifting as risk factors for low back pain. *Journal Occupational Environment Medicine*. 60: 715 – 721.

Panjabi, M.M. 1992. The stabilizing system of the spine. Part 1. Function, dysfunction, adaptation and enhancement. *Journal Spinal Disorder*. 5: 383 – 389.

Paton, C.R., Pickard, E.C. and Hoehn, V.H. 1990. Seat cushion and the ride problem, SAE *Journal*. 47: 273 - 83.

Pheasant, S. 1996. *Bodyspace, anthropometry, ergonomics & the design of work*. 2nd Ed. Great Britain. Taylor & Francis Publisher.

Pietri, F., Leclerc, A., Boitel, L., Chastang, J.F., Morcet, J.-F. and Blondet, M. 2004. Low-back pain in commercial travelers. *Scandinavian Journal of Work, Environment and Health*. 18: 52 – 58.

Pope, M.H., Goh, K.L. and Magnusson, M.L. 2002. Spine ergonomics. *Annals Review Biomedical Engineering*. 4: 49 – 68.

Porter, J.M. and Gyi, D.E. 2002. The prevalence of musculoskeletal troubles among car drivers. *Journal of Occupational Medicine*. 52: 4 – 12.

Preyde, M. 2000. Effectiveness of massage therapy for subacute low-back pain: a randomized controlled trial. *The Canadian Medical Association* Journal. 162: 1815 – 1820

Reinecke, S.M., Hazard, R.G. and Coleman, K. 1994. Continuous passive motion in seating: a new strategy against low back pain. *Journal of Spinal Disorders*. 7: 29 – 35.

Reynolds, H.M. 1993. Automotive Ergonomics. *Automotive seat design for sitting comfort*. Edited by Peacock, B. & Karwowski, W. University of Louisville.

Riihimaki, H. 1991. Low-back pain, its origin and risk indicators. *Scandinavian Journal of Work Environment Health*. 17(2): 81 - 90.

Road and Transportation Department. Statistic Data. 2007. Panducermat – Laman Web Rasmi Jabatan Keselamatan Jalan Raya Malaysia. http://www.panducermat.org.my.

Roberts, D.F. 1973. Climate and human Variability: An Addison-Wesley Module in Anthropology. No.34. Reading, MA: Addison-Wesley.

Rugulies, R. and Krause, N. 2005. Job strain, iso-strain, and the incidence of low back and neck injuries. A 7.5 – year prospective study of San Francisco transit operators. *Journal of Social Science & Medicine.* 61: 27 – 39.

Sadri, G.H. 2002. A model of bus drivers' diseases due to risk factors and bus accident. Iran Journal Medical Science. 27(1): 39 – 41.

Sander, M.S. 1987. *Applied Anthropometry and Work Space: Human Factors in Engineering and Design*. McGraw-Hill International Editions. Sixth Edition. New York.

Saporta, H. 2000. *Durable Ergonomic Seating for Urban Bus Operators*. Report for Tri-County Metropolitan Transportation District of Oregon

Shirado, O., Ito, T., Kaneda, K. and Strax, T.E. 1995. Flexion - relaxation phenomenon in the back muscles. A comparative study between healthy subjects and patients with chronic low back pain. *Am J Phys Med Rehabil*. 74: 139 – 144.

Shoemaker, J.K., Tiidus, P.M. and Mader, R. 1997. Failure of manual massage to alter limb blood flow: measures by Doppler ultrasound. *Journal Medicine and Science in Sports and Exercise*. 29: 610 – 614.

Smith, L.L., Keating, M.N., Holbert, D., Spratt, D.J., Mccammon, M.R., Smith, S.S. and Israel, R.G. 1994. The effects of athletic massage on delayed onset muscle soreness, creatine kinase, and neutrophil count: a preliminary report. *Journal Ortho Sports Physical Therapy*. 19: 93 – 99.

Tanaka, T.H., Leisman, G., Mori, H. and Nishijo, K. 2002. The effect of massage on localized lumbar muscle fatigue. *BMC Comp Alter. Med*. 2 (9).

Thomas, H. 1996. *Research Methods and Data Analysis in the Social Sciences*. Harper Collins College Publishers. New York.

Thompsonn, D.D. 2001. *Digital Human Modeling for Vehicle and Workplace Design: The Determination of the Human Factor/Occupant Packaging Requirements for Adjustable Pedal System*. USA. Society of Automotive Engineers (SAE), Inc.

Toren, A. 2001. Muscle activity and range of motion during active trunk rotation in a sitting posture. Journal of *Applied Ergonomics.* 32: 583-591.

Troup, J.D.G. 1978. Driver's back pain and its prevention. A review of the postural, vibratory and muscular factors, together with the problem of transmitted road shock. *Journal of Applied Ergonomics*. 9: 207 - 214.

Van Dieen, J.H., De Looze, M.P. and Hermans, V. 2001, Effects of dynamic office chairs on trunk kinematics, trunk extensor EMG and spinal shrinkage. *Journal of Applied Ergonomics*. 44: 739 – 750.

Van Deursen, D.L., Goossens, R.H., Evers, J.J., Van Der Helm, F.C. and Van Deursen, L.L. 2000. Length of the spine while sitting on a new concept for an office chair. *Applied of Ergonomics*. 31: 95 – 98.

Van Deursen, D.L., Lengsfeld, M., Snijders, C.J., Evers, J.J. and Goossens, R.H., 2000. Mechanical effects of continuous passive motion on the lumbar spine in seating. *Journal of Biomechanics*. 33: 695 – 699.

Videman, T. and Numinen, M. 2004. The occurrence of annular tears and their relation to lifetime back pain history: A cadaveric study using barium sulfate discography. *Spine Journal*. 29: 2668 – 2676.

Videman, T. Nurminen, M. and Troup, J.D.G. 1990. Lumbar spinal pathology in cadaveric material in relation to history of back pain: Occupation and physical loading. *Journal of Spine*. 15: 728 - 738.

Waller, P.F. and Green, P.A. 1997. Handbook of Human Factors and Ergonomics. Chapter 59 - *Human Factors in Transportation*. New York: John Wiley and Sons.

Wilder, D.G., Pope, M.H. and Frymoyer, J.W. 1988. The biomechanics of lumbar disc herniation and the effect of overload and instability. *Journal of Spine Disorders*. 1(1): 16 - 32.

Winkleby, M.A., Ragland, D.R., Fisher, J.M., and Syme, S.L. 1988. Excess risk of sickness and disease in bus drivers: A review and synthesis of epidemiological studies. *International Journal of Epidemiology*. 17: 255 – 261.

World Health Organization. 1998. *Life in the 21st century Vision for all*. The World Health Report 1998. WHO. Geneva.

World Health Organization. 1997. *Life in the 21st century Vision for all*. The World Health Report 1997. WHO. Geneva.

World Health Organization. 1986. *Teaching Health Statistics*: *Twenty lesson and seminar outlines*. Edited by Lwang, S.K and Cho-Yook Tye. WHO. Geneva.

Yamazaki, S., Banes, A.J., Weinhold, P.S., Tsuzaki, M., Kawakami, M. and Minchew, J.T. 2002. Vibratory loading decreases extracellular matrix and matrix metalloproteinase gene expression in rabbit annulus cells. *Spine Journal*. 2: 415 – 420.

Zedka, M., Prochazka, B., Knight, D., Gilliard, D. and Gauthier, M. 1999. Voluntary and reflex control of human back muscles during induced pain. *Journal Physiol*. 520: 591 – 604.